U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1529

SPRAY IRRIGATION *in the* EASTERN STATES

MANY FARMERS in the Eastern States have found the irrigation of certain crops by conveying water through pipes and spraying it on the fields from elevated pipes to be profitable. There has been a considerable demand for information on such installations, and this bulletin has been prepared to give information on planning, construction, and cost. Spray-irrigation systems are costly and should be made only after careful consideration of the probable cost and increased profit due to irrigation. The following discussion relates particularly to systems of small or only moderate size, suitable for home gardens and fields up to 4 or 5 acres in size. The ordinary beginner will do well to limit his first installation to not more than 3 acres, while considerably less will be ample for experiment.

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SPRAY IRRIGATION IN THE EASTERN STATES

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PURPOSE OF IRRIGATION IN THE EASTERN STATES

THE GENERAL PURPOSE of irrigation in the humid region is not, as it is in the arid region, to supply a normal deficiency in the annual or seasonal rainfall of the locality; it is, rather, to insure that sufficient moisture is always available when wanted, in order that maximum profits may be obtained from crops under intensive cultivation. In the Eastern States irrigation is most necessary or profitable for crops that are costly to produce, have short growing seasons, are quickly perishable when matured, and are materially affected by short periods of deficient moisture. One hot, dry period of 10 days or even less when strawberries are ripening, when lettuce is heading, or when potato tubers are setting will seriously damage or perhaps completely ruin the crop. The risk of losing the value of the great amount of labor and the cost of fertilizer necessarily expended upon special crops is greatly lessened by the installation of an adequate irrigation plant. Another advantage enjoyed by truck farmers who have spray-irrigation systems is the ability to prepare land for planting at any time in the summer, and to sprout seed in spite of dry weather.

KINDS OF IRRIGATION

There are three kinds of irrigation, according to the method of applying the water to the plants. (1) Surface irrigation consists in delivering the water over the surface of the ground by such methods as running it down the furrows or by spreading it broadcast over the tract to be irrigated. Either open ditches or pipe lines may be used to deliver the water to convenient points for distribution.[1] (2) Subirrigation consists in delivering water to a porous stratum of soil at proper depth, through which the moisture spreads to the plant roots. To prevent excessive losses by downward percolation, the porous stratum must be underlain by an impervious stratum at a rather shallow and fairly uniform depth, and to prevent saturation of topsoil where the plant roots should develop the ground surface must be

[1] SURFACE IRRIGATION FOR EASTERN FARMS. U. S. Dept. Agr., Farmers' Bul. No. 899. 36 p. Illus. 1917.

very level or have a very slight and very uniform slope. The conditions for successful subirrigation are of extremely rare occurrence. (3) Spray irrigation puts the water onto the crops in the form of very fine drops or spray or mist. It is applicable to all kinds of soils and to any condition of ground slope, and to the utilization of small water supplies that would be entirely inadequate for surface or subirrigation systems. It can be applied only in pipes under pressure.

Where sufficient water is available, the cost of a surface-irrigation system is much less than is required for a spray-irrigation system. Surface-irrigation methods, however, do not give as uniform distribution of the water as can be obtained with the spray installation, nor can the soil be kept so continuously in the best condition for growing truck crops.

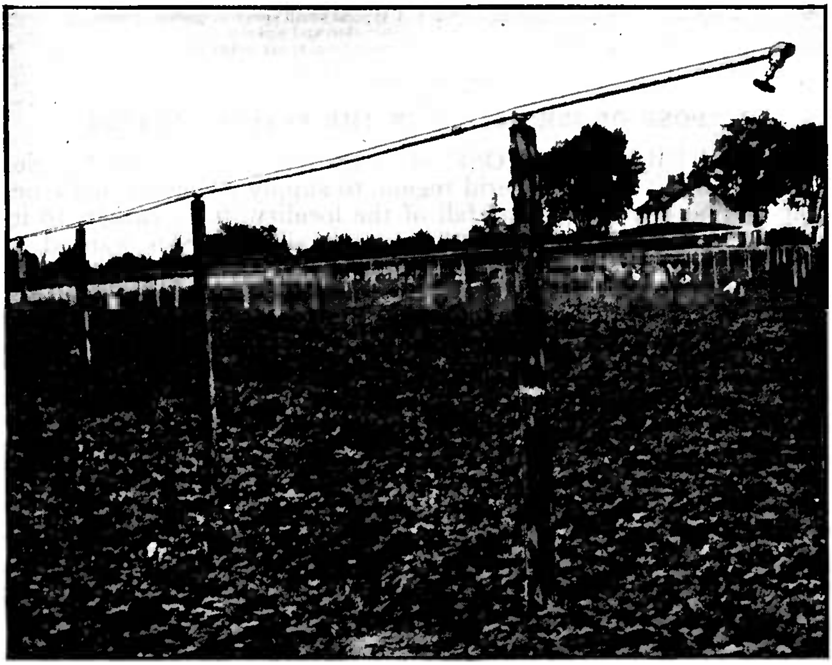

FIG. 1.—Tall post type of overhead pipe spray-irrigation equipment. (The pipes are 6½ feet above the ground)

TYPES OF SPRAY-IRRIGATION SYSTEMS

OVERHEAD PIPE SYSTEM

The irrigation system most commonly used in the eastern United States consists of parallel lines of pipe about 50 feet apart, supported on rows of posts about 6½ feet high, each line equipped with small nozzles spaced 3 to 4 feet apart, as illustrated in Figure 1. Each nozzle discharges a tiny stream of water perpendicularly to the pipe line, all streams emerging parallel. The water falls upon the ground and plants in tiny drops or as a mist; the entire width of about 50 feet may be irrigated uniformly by turning the pipe. The water for irrigation is pumped through underground pipes, to which the end of each nozzle line is connected by an upright pipe. At the

beginning of each nozzle line is a valve, a turning union equipped with a handle to turn the pipe, and a screen to catch any sediment in the water.

The kind of system just described is commonly known as a "high-post" installation. Less frequently, posts are used only 1½ to 4 feet high, and the system then is termed a "low-post" installation. Some systems have the nozzle lines suspended by short wires from a cable supported by posts 12 to 20 feet high and 50 to 125 feet apart, as illustrated in Figure 2.

A "portable" spray system such as is used in some localities consists of one or more nozzle lines that are carried from one part of the field to another as desired. They are laid upon the ground or supported on boxes, short posts, or special portable devices. Sometimes the main pipes to supply the portable nozzle lines are laid on top of the ground and moved from one field to another. Sometimes the entire piping system is stored in the barn during the winter.

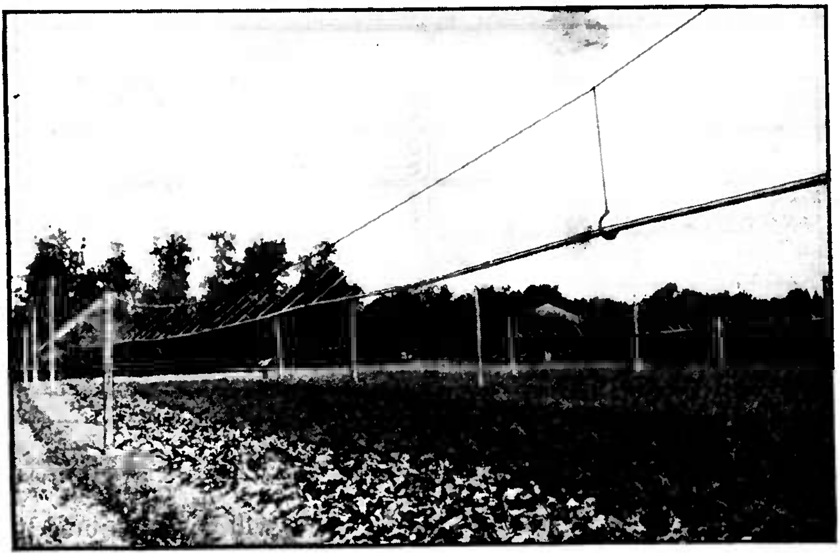

FIG. 2.—Cable suspended type of overhead pipe spray-irrigation equipment with wooden posts

The high-post installation is used by a great majority of the irrigators in the eastern United States. The low-post installation gives a slight saving in the cost of posts, but interferes somewhat more with farming operations than the high-post installation. When high posts are used, a light breeze is more effective in spreading the water over the field. The cable suspension type has the advantage of giving least interference with farming operations, particularly when the nozzle lines are hung higher; they are sometimes put 9 feet above the ground. However, with the nozzles more than 6½ feet from the ground they are much less easily cleaned.

The advantage of the portable system is lower cost than the permanent installations, less piping being required, but the cost of operation is greater owing to the additional labor of moving the pipes and making the necessary connections and disconnections. Where temporary or portable supports are used this system is entirely out of the way when plowing or cultivating.

CIRCULAR-SPRAY SYSTEM

The circular-spray system distributes water from circular-spray nozzles fixed to the tops of upright pipes, sometimes called stands, distributed uniformly through the field. For irrigation of truck crops the nozzles have an elevation of 4 to 6 feet above ground and are supplied with water through the uprights, which are placed 30 to 50 feet apart on the underground pipe lines that distribute the water from the pumps. These pipes are so arranged that the uprights, and therefore the nozzles, are spaced equidistant from each other at the corners of triangles, as shown in Figure 3. This gives a more uniform distribution of water over the field than to place the nozzles at the corners of squares or rectangles. Each lateral pipe line is controlled by a valve, and sometimes each nozzle. This system is used very little in the Eastern States, and is discussed more completely in other publications.[2] Its use is largely confined to light

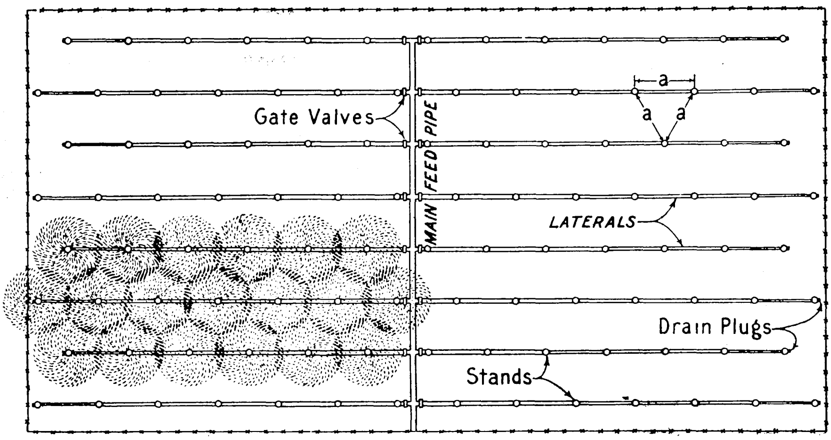

FIG. 3.—Typical plan for piping a field for a circular-spray irrigation system, showing staggered positions of nozzles to obtain the least amount of overlapping of spray. Distances marked *a* should be equal

soil that takes water rapidly and to crops that will not be injured by a coarse spray. The circular spray seems more particularly adapted for the irrigation of fruit than of vegetables, and is used to a considerable extent in the citrus orchards of California. There the stands are high, often holding the nozzles above the trees, and sometimes are placed close to trees so as to be less in the way of cultivation.

WATER SUPPLIES

COMMON SOURCES OF SUPPLY

Underground water is the source of supply for most spray-irrigation systems, particularly in the Middle Atlantic States. It is obtained generally at depths of 15 to 50 feet, though a very few irrigators have wells more than 100 feet deep. The quality of underground water for irrigation is generally good. For depths not exceeding about 50 feet, driven wells are generally used, because in the section

[2] IRRIGATION IN FLORIDA. U. S. Dept. Agr. Bul. 462. 62 p. Illus. 1917.
SPRAY IRRIGATION. U. S. Dept. Agr. Bul. 495. 40 p. Illus. 1917.

where irrigation is most common the absence of rock or bowlders permits of easy driving. Where one well has been inadequate, batteries of two to five or more wells have been used, connected together at the top. As ordinarily placed (6 to 10 feet apart) the supply is not increased in proportion to the number of wells; the flow probably would be increased by spacing the wells farther apart. The deeper wells are larger in diameter and more difficult to install than the driven type, but they furnish a larger and more dependable supply of water. Where deep wells have been used for irrigation supplies, the water generally rises to within the ordinary pumping depth, and if this does not occur the cost of pumping from deep sources may reduce greatly the profits from irrigation.

Near cities it sometimes has been practicable to procure water for irrigation from the municipal water mains. The quality of such supplies is excellent and the cost of pumping is eliminated, but with increase in the population of the city and the corresponding increase in the demand for household use the permanence of this source is not always assured.

Water for irrigation is procured in many cases from lakes, ponds, and streams. To be of value, any source of supply must furnish adequate quantities in the dry seasons, at which times the water is most needed. Very small streams, and sometimes springs, can be utilized when it is practicable to form a storage reservoir by building a dam across the waterway. Such surface waters are very likely to need straining before they are used in order to avoid clogging of the nozzles.

QUANTITY AND QUALITY OF WATER REQUIRED

The supply of water for irrigation should be ample. A spray-irrigation outfit, for the usual variety of truck crops grown, should be able to deliver at least 1 inch depth of water per week over the area to be irrigated. Though certain crops may require higher rates than this for short periods, the average of 1 inch depth per week over the entire irrigated tract will be sufficient for nearly every farm. This quantity is equivalent to 27,152 gallons per week per acre, or approximately 7½ gallons per minute per acre when pumping 10 hours per day 6 days per week.

Water for irrigation should be free from everything that would injure plants or people. Water that would be harmful to plants generally is so recognized in the locality. Water that may be contaminated with sewage should be investigated before being used. It should be free from sand or vegetable matter and from everything that would clog the nozzles or cause wear in the pump. Such material often can be strained out by suitable devices.

PLANNING A SPRAY-IRRIGATION SYSTEM

CHOOSING THE WATER SUPPLY

The first step in designing an irrigation system should be to make sure that a good supply of water is obtainable and that it will be adequate in the dryest season. All doubt in this regard should be removed before any unnecessary expense is incurred. Irrigation requires a relatively large quantity of water, and the fact that a source of supply is ample for all the other farm uses is not proof

that it is sufficient for irrigation during dry periods. If the prospective irrigator has a choice of sources of supply, the cost of original installation and of operation and upkeep for each available source and the dependability of each should be considered carefully before a choice is made.

If a new well is to be put down, it ordinarily will be located most satisfactorily on one side of the field to be irrigated, close to the line of the main distribution pipe and convenient to the irrigator's dwelling. For large irrigation systems, often the best location is nearer the center of the field. Sometimes it may be advisable to locate the well at a distance from the field, particularly if the depth to water varies greatly in different parts of the farm, or to use a well already there rather than put down a new one.

The supply obtainable from a well should be tested. This can best be done with a pump and engine running a 10-hour test. A barrel of known capacity can be set under the discharge pipe, and the time required to fill it measured once an hour during the test. The prospective irrigator should then attempt to estimate how much this flow probably will be reduced during the dryest season of the year. For watering 2 acres, 15 to 20 gallons per minute through a period of 10 hours should be obtainable at any time. This quantity is generally considered the minimum practicable to use for irrigating anything more than a home garden. For a larger area the supply should be not less than 7½ to 10 gallons per acre per minute. If more than one well is required, each succeeding one may be expected to deliver less water than the last, how much less depending upon the distance between them and nature of the water-bearing material.

If the source of supply is a lake or stream, general knowledge of the stages or flow usually will indicate whether the supply is sufficient; if it does not, the flow in a stream can be measured by a triangular weir, as described in another publication.[3] The flow of a very small stream, even sufficient to irrigate 4 acres, can be measured with a barrel or a pail. If a small wooden dam will not raise the water high enough to flow into the measuring receptacle, a barrel can be set in the bed of the stream and a count made of the number of pailfuls taken out per minute in order just to keep the barrel from overflowing. In rolling country it may sometimes be preferable to convey water through a ditch to a reservoir located near the field to be irrigated, rather than to pump directly from the stream at its nearest point. The construction of reservoirs and dams is discussed at some length in a separate bulletin.[4]

LAYING OUT THE PIPING SYSTEM

It is essential that the nozzle lines have the same direction as the crop rows, but ordinarily the rows can be changed as necessary to fit the desired arrangement of pipes. Long nozzle lines and short mains cost less for pipe and fittings, but a larger number of short nozzle lines makes it possible to irrigate small portions of the field at a time, which permits greater variation in the arrangement of the crops and the time of planting. For small installations the latter

[3] CONSTRUCTION AND USE OF FARM WEIRS, pp. 16 and 17. U. S. Dept. Agr., Farmers' Bul. No. 813, 18 p. Illus. 1917.

[4] FARM RESERVOIRS. U. S. Dept. Agr., Farmers' Bul. 828. 36 p. Illus. 1917.

advantage is of greater importance. For a field of 2 or 3 acres it is common to lay the main along one of the longer sides and run the nozzle lines across the field at right angles to the main (fig. 8, p. 23). Sometimes, particularly for large fields, it is advantageous to extend the nozzle lines both ways from a main laid through the middle of the field.

Fifteen gallons per minute will supply 300 feet of line having nozzles 4 feet apart, or a little more than 200 feet of line having nozzles 3 feet apart. Nozzle lines up to 600 or 700 feet long are in use, but only where a very large area is included under one system. Some irrigators have a decided preference for the 3-foot spacing and others for the 4-foot spacing, but both seem to work equally well in practice. The ground can be watered as fast with the nozzles at the greater distance apart as at the smaller distance, by increasing the pressure in the pipes.

The distance between nozzle lines in systems now in use ranges from 45 to 56 feet. The greater spacing requires higher pressure at the nozzles, which has a greater effect in breaking the spray into a mist that will not puddle or wash the soil, but may require a larger engine. The smaller spacing requires more posts, pipe, and fittings per acre. The most common and probably the most generally satisfactory distances are 48 and 50 feet. With the lines 50 feet apart, 871 feet of overhead pipe are required per acre.

At its connection to the main the nozzle line must have capacity to supply the entire line without undue loss of pressure. It may be reduced gradually in size to a minimum of three-fourth inch at the end. The sizes in general use which have proved satisfactory are shown in Table 1.

The upright that feeds the water from the main into the nozzle line should not be smaller than the largest pipe in the nozzle line, and one size larger is the rule in a great number of irrigation systems. Where one upright will feed two nozzle lines, on each side of the main, it should be large enough to supply both lines at once.

TABLE 1.—*Sizes of pipe for nozzle lines in spray-irrigation systems* [1]

Nozzle spacing	Total length of line	2-inch pipe	1½-inch pipe	1¼-inch pipe	1-inch pipe	¾-inch pipe
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Nozzles 3 feet apart	100				20	80
	150				80	70
	200				120	80
	250			80	100	70
	300			140	100	60
	400		120	120	100	60
	500	100	120	120	100	60
	600	200	120	120	100	60
Nozzles 4 feet apart	100					100
	150				60	90
	200				100	100
	250				160	90
	300			60	160	80
	400			160	160	80
	500		80	180	160	80
	600		180	180	160	80
	700	100	180	180	160	80

[1] Pipe ordinarily is bought in lengths of approximately 20 feet, which are threaded at both ends. The labor of cutting and fitting is least when full lengths are used, and only the smallest size (¾ inch) will need to be cut for any nozzle line.

The main pipe line should be large enough to carry the maximum quantity of water to be pumped without excessive loss of pressure due to friction in pipe. The pressure used up in overcoming friction increases in proportion to the length of the pipe, and a small decrease in the pipe size makes a very large increase in the friction to be overcome. Table 2 shows the sizse of pipe ordinarily used for mains to carry different quantities of water in spray irrigation. When the water supply is located at a considerable distance from the field to be irrigated, in occasional instances it might be economical to use a somewhat larger supply pipe and distribution main from the pump to the nozzles in order to keep down friction losses to be overcome by the pump and engine.

In the majority of overhead pipe systems the main pipe is of the same size throughout its entire length. This has the advantage of giving the most nearly uniform pressure at all the nozzle lines that will be operated at the same time, and therefore the most uniform distribution of the water over the field. It also allows for making extensions without changing the pipe. It is permissible in some cases to reduce the sizes of the end sections of the main, as has been done in some of the large installations; but this reduction should not be as great as might be inferred from Table 2, or the difference in pressure at the nozzle lines is likely to be greater than desirable.

The suction pipe of the pump usually is one size larger than the discharge pipe or distribution main of the system. It is never smaller than the main, even when it is connected to the casing of a well of smaller size.

TABLE 2.—*Sizes, weight, and cost of pipe for distribution mains in small spray-irrigation systems*

Size of pipe	Quantity of water	Approximate weight per 100 feet	Price per 100 feet [1]
Inches	*Gallons per minute*	*Pounds*	*Dollars*
¾	3 to 4	113	7.50
1	5 to 7	175	10.50
1¼	8 to 14	225	14.00
1½	15 to 22	275	16.25
2	23 to 38	375	23.00
2½	39 to 65	600	36.00
3	66 to 110	775	[2] 44.00
3½	111 to 170	925	[2] 60.00

[1] Prices of galvanized steel pipe in large cities in the Eastern States, March, 1926. In 1927 prices are slightly lower but the figures given are sufficiently close for estimating.
[2] Prices of black pipe are: For 3 inch, $37; for 3½ inch, $48.

The various fittings required for a typical nozzle line and upright and their locations are shown in Figure 4, together with the construction for crossing under a farm road. Where one upright feeds two nozzle lines, a valve must be placed on each line instead of on the upright.

The special turning union on each nozzle line permits turning the pipe without loosening the joint. It ordinarily is provided with a screen to catch scale or sediment coming up from the main. A short length of ¾-inch pipe with a cap on one end is screwed into the side opening of the turning union for a handle to turn the nozzle line. The screen is flushed by removing the cap and letting the water flow.

There are mechanical devices for automatically turning the nozzle lines, but they have not yet come into general use.

A gate valve, rather than a globe valve, should be used to control the flow to the nozzle line. At the outer end of the line a gate valve, stopcock, or special flushing valve sometimes is used instead of a cap for convenience when flushing the line. The valves and turning unions should not be of smaller size than the pipe on which they are used.

In a portable installation, either a force of men must be available to carry the whole nozzle line from one location to another or the line must be divided into sections. To make disconnecting and reassembling these sections easy, particularly the alignment of the nozzles, special "quick-acting" couplings or unions are made with a square or hexagonal projection on one part fitting into a recess of the same shape on the other part.

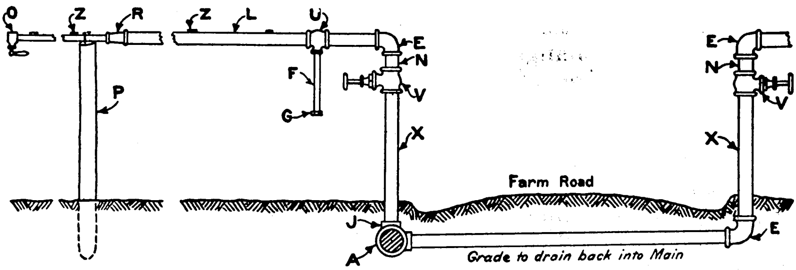

FIG. 4.—Typical fittings for overhead nozzle lines. A, underground main; J, tee (the one shown has a side opening, used only for connecting beneath the road to another nozzle line); X, upright; V, valve; N, nipple; E, elbow; U, turning union; F, pipe handle for turning line; G, cap on handle; L, nozzle line; Z, brass nozzles; R, reducer connection to smaller pipe; O, cap or flushing cock; P, post support for lines

QUALITY OF PIPE AND FITTINGS

For sizes up to 3-inch, galvanized wrought-steel pipe with threaded ends and couplings—commonly called wrought-iron pipe—should be used. This is more costly than black pipe, but it is more durable, and the amount of rust scale formed inside and liable to clog the nozzles is very much less. For sizes larger than 3-inch, the black pipe often has been used, principally because of its lower cost. However, the larger pipe, being of thicker material, lasts longer than the smaller sizes that are not galvanized. The rust scale formed in the underground pipes is not particularly troublesome in clogging the nozzles, because little of it is carried up to the nozzle lines, and that can be caught by screens in the turning unions.

The fittings, such as tees, elbows, reducers, bushings, plugs, and caps, may be of black iron on the galvanized-pipe lines, because they are not made of steel but of malleable or cast iron, which does not rust quickly. The galvanized fittings may be preferred above ground on account of appearance.

Small brass nozzles are used instead of merely holes in the side of the overhead pipe, principally to prevent enlargement of the holes by rusting, which would cause irregular distribution of the water over the field. Satisfactory nozzles are made by several manufacturers; those with the larger openings are most suitable for sandy soils and those with the smaller openings for clay soils,

SUPPORTS FOR THE NOZZLE LINES

Wooden posts are used generally for supporting the nozzle lines. For a high-post installation, 5-inch round posts or 4 by 5 inch sawed stuff are suitable, and are set 2½ to 3 feet into the ground. For a low-post installation, somewhat lighter material may be used. The lower ends, up to about 6 inches above ground surface, should be treated with wood preservative or painted with tar or creosote before they are set in the ground. Steel pipes set in concrete serve well as supports; 1 or 1¼ inch pipe or larger should be used. The posts are set 15 to 20 feet apart along the nozzle line, which will require 44 to 58 posts per acre for lines 50 feet apart.

To hold the nozzle line on the wooden posts, a stout nail is commonly driven each side of the pipe. Wooden and concrete plugs to hold the nails have been used in pipe posts. Special fixtures can be bought for this purpose which support the nozzle lines on small rollers.

For a cable suspension installation, iron pipe posts are used, 2-inch pipe for posts in the field and 3-inch pipe or 4-inch boiler tubes for the ends. They are preferably spaced 50 feet apart along the nozzle lines, which for lines 50 feet apart, requires about 18 posts per acre, depending upon the size and shape of the tract. They should be set in concrete, the end posts extending 4 feet into the ground and the others 3 feet. All are made to extend 3 to 4 feet higher than the nozzle lines. They are also filled with concrete. A small pipe inserted into the top of each end post makes a shoulder for fastening the suspension cable, and two stout screws or pins in the top of each of the other posts keep the cable from working off. The cable may be of No. 8 galvanized malleable-iron wire where the posts are not more than 50 feet apart and the nozzle line is not larger than 1½-inch pipe. It is generally fastened at each end by being wrapped twice about the small pipe in the end post and twisted on itself. An additional length of cable of 1 foot in each 50-foot span will allow a full 4-foot sag; but in determining the length of wire required, allowance must also be made for slanting of end posts and for fastening the ends. The greater the drop the less will be the strain in the cable.

The nozzle line is held in special hangers clamped to the posts and on the ends of two No. 14 wires hung from the cable in each 50-foot space between the posts. The drop wires and the cable should be double galvanized to obtain greatest durability.

Suspended systems are in use where the posts or poles are 100 or 125 feet apart, but higher posts and much stronger cable must be used in these, and each end post must be stoutly guyed against overturning into the field and against tipping sidewise. The 50-foot spacing of posts avoids the necessity for guy wires, and has the additional advantage that if the wires break the nozzle pipe will be sufficiently supported by the hangers clamped to the posts to prevent serious damage until the wire can be replaced.

PUMPING FOR SPRAY IRRIGATION

Spray irrigation requires that the water be delivered to the nozzles under considerable pressure. Further pressure is required to overcome friction in forcing the water through the pipes, and usually to lift the water from the well or stream up to the land to be irrigated. To obtain this pressure, pumps must be installed for most systems; they are used in practically every spray-irrigation system in the East, except those that obtain the water from municipal supply mains.

KINDS OF PUMPS

The type of pump commonly used for small irrigation systems is the simplex double-acting piston pump. It has but one cylinder and discharges water at both the forward and backward movement of the piston. To reduce pulsation in the pipe lines, it is particularly desirable that the simplex pumps be double-acting and that there be an air chamber on the outlet. Figure 5 shows a pump of this type. Pumps with two and three cylinders, known as duplex and triplex pumps, respectively, are adapted for large irrigation installations. The piston pump is convenient, as it is self-priming when properly installed, and but little attention is required to keep it in good condition. When water is scarce and the drawing down of the water in the well admits air to the pipe, this pump will pick up its suction again as soon as the water covers the opening.

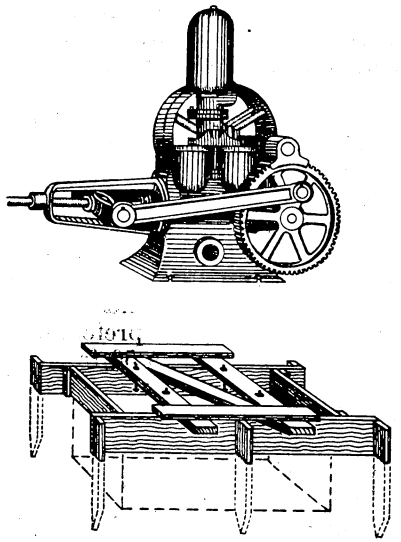

FIG. 5.—A simplex double-acting pump, over a frame holding the anchor bolts in place on a form for a concrete foundation

Where the water will stand at times below ordinary suction depth and it is not desired to put the entire pump in a pit, a deep-well pump can be used, with the cylinders set as low as necessary in the well casing or in a deep pit, and the pistons operated by long rods from the working head above ground. This pump is more costly than the simpler kind and requires a larger pipe than ordinarily is practicable for a driven well. Piston pumps may be obtained to meet all ordinary requirements of spray irrigation.

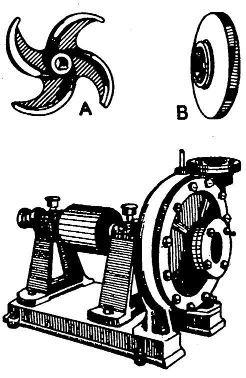

FIG. 6.—A centrifugal pump, showing both open type (A) and closed type (B) of impeller

The centrifugal pump is well adapted to spray irrigation where a plentiful supply of water is available at shallow depth. It is not self-priming, and if it sucks even a small amount of air its efficiency is greatly reduced or it will not pump water at all. It should therefore be set as near the water as possible. It can be set below the water level by putting it in a pit, and thus avoid the annoyance and labor that is caused by the pump losing priming, but this is a costly installation for a small outfit. There are two types of centrifugal pumps—(1) the volute pump which has an open impeller, and (2) the turbine pump which has an inclosed impeller (fig. 6). The turbine type is more efficient and more costly, and is suited to higher pressures than the other. Manufacturers' ratings of centrifugal pumps of the same size and style differ considerably with regard to capacity, pressure, and required power.

Centrifugal pumps for delivering less than about 50 gallons per minute cost about one-third as much as piston pumps. However, with a centrifugal pump it is usual to have either a foot valve on the end of the suction pipe or a check valve on the discharge from the pump, and there should also be a gate valve on the discharge pipe. The pump can not be primed without the use of at least one of these valves. Some sort of device for filling the pump casing, when priming, is necessary. (See p. 18.) A centrifugal pump will not break the machinery or piping if started with all valves closed, but this advantage is of little importance with small pumps.

Rotary pumps are made in sizes suitable for spray irrigation, but few of this type have been used for this purpose. They give a flow practically free from pulsation and are self-priming when in good condition; but even a small quantity of sand or fine grit in the water will wear the cams or gears and greatly reduce the quantity of water pumped.

SIZE OF PUMP REQUIRED

In the Eastern States, a pump rated at about 33 gallons per minute capacity is generally considered the minimum size for irrigation outfits where that much water is available; smaller sizes are made, and often are used for home gardens. If the water is available, a larger pumping and main pipe capacity than the minimum 7½ gallons per minute per acre will make it possible to irrigate the land without running full time, which often is desirable. Table 3 shows the rated capacities of different sizes of piston pumps commonly used in spray irrigation. As ordinarily operated, piston pumps discharge slightly less than the capacities given in manufacturers' catalogues when operated at the rated speed. A reduction of 5 to 15 per cent from the capacities shown in the table will be sufficient for determining the size of the pump required when working under a pressure of 45 pounds per square inch or less.

TABLE 3.—*Representative sizes of simplex double-acting piston pumps used in small irrigation systems, together with their weight and price*

Size		Rated capacity [1]	Shipping weight [2]	Approximate price [3]
Diameter of piston	Length of stroke			
Inches	*Inches*	*Gallons per minute*	*Pounds*	*Dollars*
3	4	10	300	75
3	5	12	300	80
4	4	17	400	90
4	5	21	400	100
5	5	33	550	120
6	6	57	850	165
6	10	95	1,100	225

[1] Computed at 40 revolutions per minute; the smallest sizes may be run at slightly increased speed under ordinary conditions. Most manufacturers advise that the speed be reduced proportionately when the pressures exceed 45 pounds per square inch.
[2] These figures represent approximate averages; some of the larger pumps may differ more than 100 pounds from the weight stated.
[3] Different makes of pumps vary considerably in price; these averages applied in March, 1926, in large cities in the Eastern States. To May, 1927, there has been no material change in prices.

An increase in pressure on a piston pump up to about the limit for which it is designed increases the power required, but does not appre-

ciably affect the quantity of discharge if the speed of operation is maintained. Many of the pumps are designed to run at 40 revolutions per minute under pressures up to 40 or 45 pounds per square inch, but may safely be used with pressures 50 to 100 per cent greater if the speed is reduced proportionately.

Some newer types of pump with much smaller pistons are designed to give as great capacities by running at much higher speeds. They weigh much less and cost about the same as those in the table for equal capacities. These are designed for pressure up to 100 pounds per square inch.

In using a centrifugal pump a small reduction in speed or increase in pressure from those at which the pump is rated will reduce the discharge in considerably greater degree. On the other hand, a considerable increase in speed or reduction in pressure from those for which the rating was made will not give a proportionate increase in capacity. A pump of this kind should be used only where the pressure will be safely within the limits set by the manufacturer.

MEASUREMENT OF PRESSURE OR HEAD ON THE PUMP

The pressure on the pump is the amount that is required (1) to lift the water from the well or other source of supply up to the nozzles, (2) to overcome friction in forcing the water through the pipes, and (3) to throw the water as far as necessary out of the nozzles. Water pressure is stated for convenience in feet of head or lift, which is the depth of water necessary to cause that pressure. A pressure of 1 pound per square inch is practically equivalent to 2⅓ feet of head or lift; therefore a pressure of 30 pounds per square inch may be considered as equal to a head of 70 feet.

The actual lift of water for any system will be the vertical distance of the highest nozzle above the water level in the well or other source of supply. This height is measured from the lowest level at which the water will stand, and in taking from a well allowance must be made for the drawdown when the pump is being operated. The computation of the actual lift ordinarily is made in three parts—first, from the water level up to the pump; next, from the pump to the highest point in the field; and last, from the ground up to the nozzle line. It is difficult to measure the depth to water level in a well when the pump is operating, but the actual lift and the friction head together in the suction pipe ordinarily should not exceed 20 feet, although in some cases pumps have worked satisfactorily when the actual lift and friction head were nearly 30 feet. Therefore it is convenient, and generally it is advisable, to use the latter figure for the total head up to the pump.

The head necessary to overcome friction in a pipe depends upon the length of the pipe, its size, and the quantity of water carried. Table 4 shows the number of feet of head required to overcome friction in each 100 feet of wrought-steel pipe of different sizes carrying different rates of flow, and may be used in computing the head used up in the discharge pipe or distribution main of the system.

The pressure at the nozzle lines should be at least 15 pounds per square inch, and more if the distance between the lines exceeds 50 feet.

TABLE 4.—*Number of feet of head required to overcome friction in each 100 feet of common steel pipe*

[Based on Williams-Hazen formula, using a coefficient of 100]

Quantity of water	Number of feet of head required for the size of pipe indicated							
	¾-inch	1-inch	1¼-inch	1½-inch	2-inch	2½-inch	3-inch	3½-inch
Gallons per minute	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
5	10.5	3.25	0.84					
6	14.7	4.55	1.20					
8	25.0	7.80	1.59	0.95				
10	38.0	11.70	2.05	1.43	0.50			
12		16.40	4.30	2.01	.70			
14		22.00	5.70	2.68	.94	0.32		
16			7.30	3.41	1.20	.41		
18			9.10	4.24	1.49	.50		
20			11.10	5.20	1.82	.61	0.25	
25			16.60	7.80	2.73	.92	.38	
30			23.50	11.0	3.84	1.29	.54	
35				14.7	5.10	1.72	.71	0.32
40				18.8	6.60	2.20	.91	.41
45				23.2	8.2	2.76	1.15	.51
50					9.9	3.32	1.38	.62
60					13.9	4.65	1.92	.89
70					18.4	6.20	2.57	1.11
80					23.7	7.90	3.28	1.46
90						9.80	4.08	1.80
100						12.00	4.96	2.22
120						16.80	7.00	3.10
140						22.30	9.2	4.20
160							11.8	5.25
180							14.8	6.30
200							17.8	7.7

The sum of the pressure head, vertical lift, and friction head is the total effective head on the pump. This total head, in feet, is multiplied by the number of gallons per minute pumped and then divided by 4,000 to give the useful horsepower output of the pump, which is used in determining the size of engine needed. (See p. 15.)

ENGINES AND MOTORS

To operate the pumps, some kind of engine or motor must be used. Dependability, convenience, and cost are the considerations in choosing the kind of power to use.

Gasoline engines are the most generally available and most commonly used source of power for spray irrigation in the eastern United States. If kept in good condition they are very dependable. Any of the ordinary types of gasoline engines, with either horizontal or vertical cylinders, may be used if they furnish the desired power.

Electricity probably is the most satisfactory power when available, but, doubtless because of the cost, has been used for very few spray-irrigation systems. The motors are dependable, require very little attention, and are nearly noiseless. For irrigation outfits, moisture-resistant insulations should be used, and the motor should be so placed that water will not get into it. The first cost of an electric motor is somewhat greater than that of a gasoline engine of the same power and the cost of current at present prices exceeds the cost of gasoline. The cost of the service wires from the power line to the pump location is frequently great enough to prohibit the use of electricity for power.

TABLE 5.—*Horsepower rating required of gasoline engines for pumping against heads of 30 to 200 feet in spray irrigation*

[Over-all efficiency of pump and engine estimated as 30 per cent]

Quantity of water	Number of horsepower required against total head on pump in feet as indicated												
	30	40	50	60	70	80	90	100	120	140	160	180	200
Gals. per minute	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*	*Horse-power*
5	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.7	0.8	0.8
10	.3	.3	.4	.5	.6	.7	.8	.8	1.0	1.2	1.4	1.5	1.7
15	.4	.5	.6	.8	.9	1.0	1.1	1.3	1.5	1.8	2.0	2.3	2.5
20	.5	.7	.8	1.0	1.2	1.4	1.5	1.7	2.0	2.4	2.7	3.0	3.4
25	.6	.8	1.1	1.3	1.5	1.7	1.9	2.1	2.5	3.0	3.4	3.8	4.2
30	.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	3.0	3.5	4.0	4.6	5.1
35	.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.5	4.1	4.7	5.3	5.9
40	1.0	1.4	1.7	2.0	2.4	2.7	3.0	3.4	4.0	4.7	5.4	6.1	6.7
45	1.1	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.6	5.3	6.1	6.8	7.6
50	1.3	1.7	2.1	2.5	3.0	3.4	3.8	4.2	5.1	5.9	6.7	7.6	8.4
60	1.5	2.0	2.5	3.0	3.5	4.0	4.6	5.1	6.1	7.1	8.1	9.1	10.1
70	1.8	2.4	3.0	3.5	4.1	4.7	5.3	5.9	7.1	8.3	9.4	10.6	11.8
80	2.0	2.7	3.4	4.1	4.7	5.4	6.1	6.7	8.1	9.4	10.8	12.1	13.5
90	2.3	3.0	3.8	4.6	5.3	6.1	6.8	7.6	9.1	10.6	12.1	13.7	15.2
100	2.5	3.4	4.2	5.0	5.9	6.7	7.6	8.4	10.1	11.8	13.5	15.2	16.9

The engine or motor for spray irrigation must develop sufficient power to operate the system under maximum load—that is, when the total pressure or head on the pump is greatest. The horsepower output of the pump, computed as stated above, should be multiplied by about 3⅓ to determine the horsepower rating of the engine required for outfits to irrigate up to 5 or 10 acres. This calls for somewhat more power in proportion to the work done than usually is considered necessary for large power installations, but it is according to common practice, and the extra allowance for ordinary conditions of farm operation seems justified by experience. Table 5 shows the horsepower required for engines pumping against total heads of 30 to 200 feet for spray irrigation. In buying an engine it is better to choose one with considerable excess of power than one rated somewhat less than the amount that will be needed. Table 6 shows the ordinary horsepower ratings of small gasoline engines of the common type.

TABLE 6.—*Weight and cost of representative sizes of gasoline engines used in small spray-irrigation systems*

Rating	Weight [1]	Price [2]
Horsepower	*Pounds*	*Dollars*
1½	250	50
2	300	60
3	475	80
5	850	115
7	1,200	160
9	1,850	240

[1] These figures represent only approximate averages.
[2] Different classes of engines vary widely in price; suitable engines could be bought at these prices in March, 1926, in large cities in the Eastern States. To May, 1927, there has been no material change in prices.

INSTALLING THE SYSTEM

The installation of a spray-irrigation system comprises the following steps: (1) Procuring the water supply; (2) installing the pumping equipment; (3) laying the mains; (4) screwing the uprights into the main; (5) setting the posts for the nozzle lines; (6) putting together and tapping the nozzle lines; (7) flushing out the pipes by pumping; (8) screwing in the nozzles.

PROCURING THE WATER

The methods of driving wells are generally understood in those localities where absence of rock or bowlders permits this kind of installation, but if information is desired they are explained in another publication.[5] The construction of bored or drilled wells requires special equipment, and should be done by persons experienced in the work.

If a dam is built to form a reservoir, consideration must be given to the likelihood of causing injury by flooding lands above. Also, the dam should be made secure against injury from floods, and

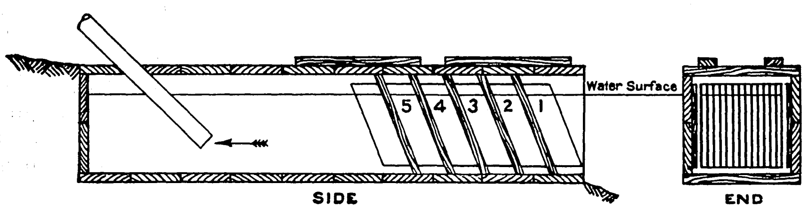

FIG. 7.—A screen box with five screens for surface water

provision made for water to pass over or around the dam when the reservoir is full. In most cases where the water will be taken from a small stream, the construction of a low dam will be of advantage in maintaining a fairly uniform water level while irrigating.

A SCREEN FOR SURFACE WATER

When using surface waters for spray irrigation, a screen must be provided to keep out trash and fine sediment that would wear the pump or clog the nozzles. Anything may be used that will accomplish this purpose. An inexpensive device for a supply of about 50 gallons per minute or less is a wooden flume, such as is shown in Figure 7. It consists of a wooden box about 10 feet long by 2 feet wide and 1½ to 2 feet deep below low-water level, with removable screens. The number of screens may vary from three to five, depending somewhat upon the kind of trash and sediment in the water. The screens are placed 6 to 8 inches apart. The outer one usually should be of vertical rods or bars about 1½ inches apart to catch the coarsest material; the second of heavy galvanized wire screen about ¼-inch mesh; the third of window-screen mesh, preferably of copper because of its greater durability; the fourth of perforated sheet brass or of cheesecloth. The holes in the brass should be as small as the holes in the spray nozzles. The cheesecloth is much

[5] FARMSTEAD WATER SUPPLY. U. S. Dept. Agr., Farmers' Bul. 1448. 40 p. Illus. 1925.

cheaper, but needs to be renewed very frequently; usually two cheesecloth screens are used instead of only one. The cloth is more effective in taking out the fine fibers of muck carried in some of the sluggish coastal streams. The screens will need cleaning more or less frequently, and extra cloth screens should be kept on hand to make replacements promptly as needed. This flume may be set in a ditch or trench dug out from the side of the stream or reservoir. A cover to keep out leaves and wind-blown trash usually is desirable, made in sections for easy removal.

SETTING THE PUMP AND ENGINE

The pump should be installed close to the well or other source of supply. It should be low enough to be within the practical suction lift of the water when it is drawn down by pumping.

In small installations the pump is usually belt driven. Direct-connected and gear-driven installations are more compact and somewhat more economical of power when properly set up, but in small outfits the saving in operating cost does not justify the extra cost of the higher grade equipment. Belts of different kinds and of varying quality and price are obtainable. Waterproof belts, while more costly, are much more durable than other kinds if exposed to moisture.

The pump and engine should be lined up very accurately. To keep the belt from running off, the pulleys on the pump and engine must revolve in the same plane. The centers of the pulleys, for a belt-driven outfit of this size, ought to be 8 or more feet apart, unless a tightening pulley is used.

FOUNDATIONS

Concrete foundations are best for the pump and engine. A rough rule is to make the foundation 6 inches longer and 6 inches wider than the machine and the depth equal to two-thirds of the height of the machine. For vertical cylinder pumps or engines the depth of foundation may be considerably less in proportion to height of machine. The top of the foundation may be about 6 inches above the floor or ground. Where the pump is direct connected to the engine or is driven by gears or chain, both pump and engine should be set on one block of concrete. For small belt-driven installations a cheap arrangement sometimes used instead of more permanent foundations is to bolt the pump and the engine to the opposite ends of two heavy timbers fastened rigidly together.

The anchor bolts for fastening the machinery to the foundation should be very accurately placed, which may be done by making a light but thoroughly braced framework to hold the bolts in position while the concrete is poured. It will be advisable to set up the machine on the loose timbers, then fasten them rigidly together, and mark the bolt locations. Figure 5 shows such a framework in position on the form for the concrete base. To avoid the painstaking labor of setting anchor bolts accurately in a concrete foundation, a plan sometimes followed has been to bolt two good planks on top of the concrete and fasten the machinery to the planks.

The concrete for the foundations may be proportioned about 1 part of Portland cement to 2 parts of clean sand and 4 parts of crushed rock or gravel. When crushed rock or gravel is not available, 1 part

cement to 4 of sand may be used. The foundation for a 5 by 5 inch pump will require about one-third of a cubic yard of concrete and that for the three-horsepower engine about the same. A 1 : 2 : 4 mixture of cement, sand, and gravel for these foundations would require 4 bags of cement and approximately 0.3 cubic yard of sand and 0.6 cubic yard of gravel. For the 6 by 6 inch pump and five-horsepower engine, about one-fourth more of each material would be required. The ingredients of the concrete should be thoroughly mixed while dry, and then only enough water added—a little at a time while the mixing is continued—to thoroughly moisten them. After placing in the form the concrete should be covered and kept wet for several days. The proportioning and handling of concrete is fully explained in another publication.[6]

The top of the foundation should be carefully leveled. After the machinery is placed a cement grout should be worked in all around the base and allowed to harden before the bolts are tightened. The grout should be made of cement, or of equal parts of cement and sand, mixed with water to about the consistency of thick cream.

SUCTION PIPE AND PRIMING

The suction pipe of the pump should have as few bends as practicable, and should slope continuously upward from the water to the pump, so that no air pockets will be formed. Particular care should be taken to see that the joints in the pipe are air-tight, preferably by coating the threads with white lead just before the pieces are screwed together.

Where the water is obtained from driven wells the suction pipe of a piston pump is ordinarily attached directly to the well casing. Centrifugal pumps are almost never used in connection with small driven wells, and where used in connection with those having 3-inch casings or larger a separate suction pipe is usually dropped inside.

A centrifugal pump must be primed by filling the pump casing and suction pipe with water before starting the pump. Where a foot valve is used a convenient arrangement is a tank placed higher than the pump, and a pipe from the bottom of the tank to the top of the pump casing with a hand valve on this pipe. Another arrangement is a small hand pump in place of the priming tank, the valve on the main discharge pipe being closed before beginning to operate the hand pump. No priming of a piston pump is necessary when it is in good condition.

LAYING THE MAINS AND SETTING THE UPRIGHTS

The underground mains should be deep enough so they will not interfere with cultivation, and should be sloped so they can be drained at convenient places. The locations of the pipes should be determined carefully. The trenches ordinarily are first opened by a plow and deepened by further plowing, the loosened material being thrown out by hand. The pipe is screwed together on timbers laid across the trench, so the joints can be fitted easily and tightly. A length of 200 feet or more can be fitted together and allowed to sag gradually into the trench as the length is increased.

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[6] PLAIN CONCRETE FOR FARM USE. U. S. Dept. Agr., Farmers' Bul. No. 1279. 29 p. Illus. 1922.

Provision must be made for draining the system before freezing weather in the fall. If the main rises continuously from one end to the other, or if it rises continuously from both ends to one highest point between, it can be drained by taking out one or both end plugs. At the bottom of every sag in the main a tee should be placed in the line, with the opening at one side, this opening to be closed with a plug when the system is being used.

Cutting and threading the larger sizes of pipe by hand is very laborious, and for larger than 2-inch pipe should be done in a machine-shop rather than in the field. This requires that the measurements between special fittings, such as elbows, tees, and valves, be carefully made, so that the shop can fit the pieces together just as they will be placed in the ground. A tee is used on the main for the upright at each nozzle line, including the end ones, and plugs used to close the ends of the main. Heavy graphite grease should be applied to each joint after one or two turns have been made in screwing the pipe together. White lead should not be used on the distribution mains or nozzle lines, as it may get inside the pipe and clog the nozzles.

After the main is laid the upright pipes should be screwed into the tees. Before being set up these pipes should be cut to the right length and threaded to receive the valves and other fittings that will go on top. When convenient, the uprights may be fully assembled before being screwed into the main, with all the fittings in place and ready for the nozzle line pipes to be attached.

SETTING THE POSTS

Next the posts should be placed to support the nozzle lines; the upright pipe serves as the first one in each line. The posts should be carefully lined up from both directions, like the trees in an orchard. It will be best to place first the outside posts around the field; then the interior ones can be readily lined up with them. The posts are usually placed 15 to 20 feet apart along the nozzle lines. Wooden posts, after being properly placed, are cut off either at a uniform elevation for each lateral or at a uniform height from the ground. Either way will give a field of good appearance if the posts have been carefully lined up.

When pipes are used for posts, a 6-inch post hole is dug about 2 feet deep and the pipe driven into the bottom of this sufficiently to bring the top to the required height. Then the hole is filled with concrete, making an excellent support. The concrete required for setting pipe posts will be about three-fourths cubic yard for 50 posts, where 6-inch holes 2 feet deep are made. For this quantity of 1:2:4 concrete, 5 bags of cement, 0.4 cubic yard of sand, and 0.7 cubic yard of gravel or stone will be sufficient and will allow for a small amount of waste in handling.

For a cable suspension installation the end poles are set first, about 4 feet into the ground, slanting slightly outward. The other posts are set vertically and not so deep. If pipe is used it is filled with a mortar made of about 1 part of cement and 4 parts of sand, just wet enough to be worked easily into the pipe. The small pipe or pins, as suits the location, are inserted in the tops.

ASSEMBLING THE NOZZLE LINES

After the posts are set the nozzle lines should be put together and the joints screwed tight. All dirt and scraps of metal should be carefully removed from each section before joining it to the others. A turning union should be screwed on the end of the line.

Unless the nozzle lines have been bought complete the pipe must be drilled and tapped for the nozzles. For this the assembled pipe line should be supported about 4 feet above the ground. When a high-post system is being installed heavy spikes may be driven into the wooden posts at the proper height or a wire can be wrapped tightly twice around each pipe post several inches above the desired height and a loop hung down to hold the pipe. The line must be fastened against turning while being drilled. This is best done by pointing the handle of the turning union upward, putting an elbow in place of the cap on the end of the handle, and screwing a 10 or 12 foot length of pipe into this elbow so it will rest on the ground. The nozzle-hole locations then are spaced with a stick of the proper length and marked with crayon.

To get the nozzles in a straight line along the pipe a special machine made for drilling and tapping nozzle lines should be used. It hangs from the pipe and drills in the lower side of it. Lard oil or screw-cutting oil should be used for lubricating the drill and is applied by dropping it on the upper side of the pipe and letting it run down to the drill. When the line has all been tapped it is placed on the top of the posts and connected to the upright pipe.

The entire piping system should be thoroughly flushed out before the nozzles are screwed into place. The caps on the ends of the nozzle lines are removed, or the valves opened if valves are used instead of caps, and a strong flow of water pumped through each line. Iron chips get into the line during tapping and these must be gotten out before the nozzles are put in and the system is ready for use. Covering the main pipes in the trenches is usually the last step of constructing the irrigation system. It is well not to do this before starting the pump, in order that any leaks in the line may be seen and repaired.

COST OF SPRAY IRRIGATION

A close estimate of the cost of any proposed irrigation system can be made only by taking into consideration the location of the farm, the time when the work will be done, and the conditions of that particular installation. Prices of materials and of labor differ widely in different States and localities and vary considerably from time to time. For some of the items necessarily included in any cost estimate, prices prevailing early in 1926 are given in the tables in this bulletin; for other items it is impracticable to suggest prices. When second-hand materials of suitable quality are obtainable a considerable saving in cost sometimes can be made by using them.

The cost of wells depends entirely upon local conditions. The amount of damming or ditching to get water from a stream or lake will be different for nearly every installation using surface water. The materials for the box and screens described on page 16, if new, would cost probably $10 to $12 if the cloth is used instead of a perforated brass plate.

Differences in the size and shape of the field to be irrigated and in the arrangement of main pipes and nozzle lines will affect the cost

of the piping system slightly, but at present prices the average cost of the pipe and fittings for fields of 1 to 5 acres in the eastern United States probably will be between $175 and $200 per acre, including freight. If the pump is located at a distance from the field, the cost of the additional pipe may be estimated from the prices in Table 2. The cost of the suction pipe will not be great, but it and the necessary fittings should not be overlooked when making up the bill of materials (see Table 7), particularly if the pipe is bought in a distant city.

The brass nozzles cost about $5 per hundred. The special machine for tapping the nozzle-line pipes should be purchased, if it can not be borrowed or rented. This machine and the common pipe-fitting tools probably will cost $35 to $40 if new.

Tables 3 and 6 give approximate prices at which piston pumps and gasoline engines can be bought in the large cities of the Middle and North Atlantic States; the tables also give approximate weights, to assist prospective purchasers in estimating freight charges.

TABLE 7.—*Bill of materials and estimate of cost for a typical spray-irrigation system for a field 200 by 400 feet (see p. 22)*

STANDARD PIPE AND FITTINGS

Quantity and kind of material	Approximate weight	Estimated cost [1]
	Pounds	*Dollars*
660 feet ¾-inch galvanized pipe	745	49.50
960 feet 1-inch galvanized pipe	1,680	100.80
60 feet 1¼-inch galvanized pipe	135	8.40
380 feet 2-inch galvanized pipe	1,425	87.40
16 ¾-inch galvanized caps		.96
8 1 by ¾ inch galvanized reducers		1.20
8 1-inch galvanized long nipples		.88
8 1¼-inch galvanized long nipples		1.28
8 1¼ by 1 inch galvanized reducing elbows		2.16
8 2 by 1¼ inch black tees		4.00
1 2-inch black tee	100	.65
2 2-inch black plugs		.16
3 2-inch galvanized elbows		1.50
2 2 by 1½ inch galvanized bushings		.40
2 1½ by 1¼ inch galvanized bushings		.28
1 2-inch galvanized tee		.65
3 2-inch galvanized unions		2.10
8 1¼-inch brass gate valves		14.80
	4,085	277.12

PIPE-FITTING TOOLS AND SUPPLIES

Quantity and kind of material	Approximate weight	Estimated cost [1]
1 pipe vise for ¾-inch to 2-inch pipe		
1 pipe cutter for ¾-inch to 2-inch pipe		
1 stock and set of dies for threading each size of pipe, ¾-inch to 2-inch		20.00
2 18-inch pipe wrenches	80	
½ pound white lead for suction-pipe joints		.15
2 pounds graphite grease for main and nozzle-line pipe joints		.20
1 quart machine oil for cutting and threading pipe		.20
	80	20.55

SPECIAL IRRIGATION FITTINGS AND TOOLS

Quantity and kind of material	Approximate weight	Estimated cost [1]
8 1-inch galvanized turning unions		22.00
550 brass irrigation nozzles		27.50
1 nozzle wrench	80	.15
1 special drilling and tapping machine		15.00
16 ounces lard oil for drilling nozzle line pipe		.75
	80	65.40

[1] Estimated at prices obtained in March, 1926, not including freight.

TABLE 7.—*Bill of materials and estimate of cost for a typical spray-irrigation system for a field 200 by 400 feet*—Continued

PUMPING MACHINERY

Quantity and kind of material	Approximate weight	Estimated cost
	Pounds	*Dollars*
1 5 by 5 inch simplex double-acting pump	550	120.00
1 3-horsepower gasoline engine	475	80.00
4 sacks Portland cement		(2)
½ cubic yard sand		(2)
1 cubic yard broken stone or gravel		(2)
	1,025	(2)

SUPPORTS FOR NOZZLE LINES

Quantity and kind of material	Approximate weight	Estimated cost
80 5-inch wooden posts, 9½ feet long		(2)
20 gallons creosote wood preservative for posts [3]	200	11.00
3 pounds 12-penny nails to hold lines on posts		.15
	200	(2)

WATER SUPPLY

Quantity and kind of material	Approximate weight	Estimated cost
2 1¼-inch driven wells, installed		(2)

MISCELLANEOUS

Quantity and kind of material	Approximate weight	Estimated cost
Freight		(2)
Hauling		(2)
Labor (including owner), 2 men 8 days each		(2)
House for pumping machinery		(2)
Total cost of the irrigation system		(2)

[2] Cost of these items is subject to great variation according to time and location, and to local sources of supply for some materials.
[3] If pipe posts are used, materials for concrete in which to set the posts would be substituted for this item.

Prices for cement and other ingredients of concrete vary greatly and sometimes change rapidly from week to week. The cost of posts for supporting the nozzle lines also depends upon local conditions.

Prices of labor vary with locality and season, and the owner of the irrigation system may do much of the work of installation. Two men working together should be able to lay the main pipe, set the posts, and assemble and tap the nozzle lines for 1 acre in two or three days; one man alone would require more than twice as long. Additional time would be required for installing the pumping plant.

The best estimate of cost for any proposed installation may be made by preparing a bill of materials (see Table 7) and getting quotations from the most convenient dealers, adding freight charges, and getting local estimates of the cost of a well or dam.

A TYPICAL SMALL SPRAY-IRRIGATION SYSTEM

A concrete example of the design of a small spray-irrigation system may help beginners in irrigation to apply the foregoing general discussion to their own particular situations. For the following illustration it is assumed that irrigation is being planned for a field 200 by 400 feet, which would comprise 1.84 acres, and that water will be obtained from two 1¼-inch driven wells spaced 10 feet apart.

For convenience in irrigating the field in sections (for the whole of each nozzle line must be operated at one time) the main pipe should be laid lengthwise of the field, and eight nozzle lines run across the field 50 feet apart (fig. 8.) If the nozzles are to be spaced 3 feet apart, each nozzle line should consist, according to Table 1, of 120 feet of 1-inch pipe and 80 feet of ¾-inch pipe. If the water supply obtainable is as much as 30 gallons per minute, which is twice the minimum required for this area, the pump should deliver this quantity. A 2-inch pipe should be used for the main (see Table 2), which will permit operating two nozzle lines at the same time. The main may be laid in a trench 15 inches deep, since a covering of 12 inches of soil ordinarily is ample to place it below plow depth. The upright pipe for a high-post installation would be 7 feet 6 inches long, including the valve and the nipple or short pipe above; it should be of 1¼-inch size in this case, because of the rather long length of 1-inch pipe in the overhead line.

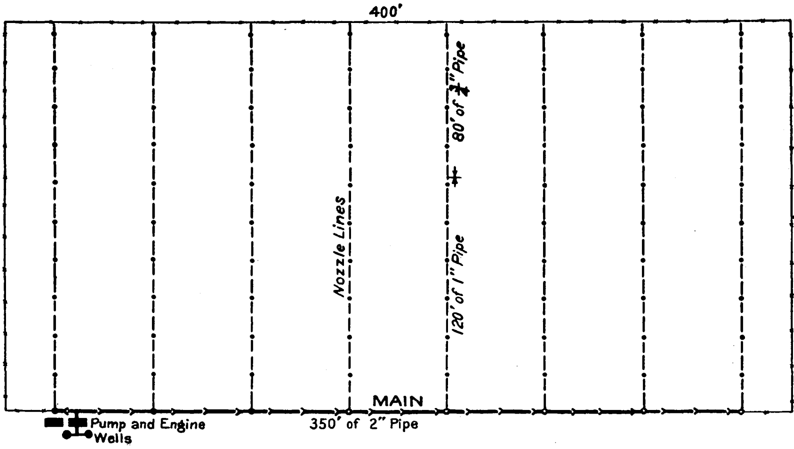

FIG. 8.—Typical small spray-irrigation system

The pipe and fittings for each of the eight nozzle lines would consist of one ¾-inch cap for the end, 80 feet of ¾-inch pipe, one 1-inch to ¾-inch reducer, 120 feet of 1-inch pipe, one 1-inch turning union, about 2 feet of ¾-inch pipe for a handle to turn the line, a ¾-inch cap for this handle, one 1-inch nipple 6 inches long between the turning union and the upright, and 67 brass nozzles. Each upright will consist of one 1¼-inch to 1-inch reducing elbow at the top, one 1¼-inch nipple 6 inches long, one 1¼-inch brass gate valve, and a little less than 7 feet of 1¼-inch pipe to make the total length 7 feet 7½ inches. The main will require 350 feet of 2-inch pipe, eight 2-inch by 1¼-inch tees where the uprights are connected, and two 2-inch plugs to close the ends. If there were one or more sags in the line, the same number of 2-inch tees and plugs would be needed in addition for draining the system. The connection to the pump will require additional fittings according to circumstances. The simplest connection, with the well and pump close beside the main, would require only a 2-inch tee on the main, a vertical length of 2-inch pipe 3 to 4 feet long, a 2-inch elbow, and 2½ feet of 2-inch pipe to reach

the pump. It would be well to put a 2-inch union in this pipe. The pump might be set between the two wells, and a 2-inch suction pipe used with an elbow and two bushings at the top of each well. This would require about 12 feet of 2-inch pipe, one 2-inch tee, two 2-inch elbows, two 2-inch to 1½-inch bushings, two 1½-inch to 1¼-inch bushings, and two 2-inch unions. To support each nozzle line at 19½-foot intervals, 10 posts will be required, 9 or 9½ feet long, for a high-post installation.

If the water supply exceeds 20 gallons per minute for a field of this size, doubtless the 5 by 5 inch pump shown in Table 3 would be selected. It will be assumed that 30 gallons per minute will be available and will be used at times. It will be assumed, further, that the well and pump are located at one end of the main pipe and that the highest ground in the field is 7 feet above that at the pump. The water pressure desired at the nozzle lines may be 20 pounds per square inch, somewhat more than the minimum stated on page 13. The total head on the pump will be computed as follows:

	Feet
Maximum suction (lift and friction; see page 13)	30
Rise of ground surface	7
Height of nozzles above ground	6½
Friction in 2-inch main, 350 feet (Table 4)	13½
Pressure at nozzle lines (20 pounds)	47
Total head	104

While this head slightly exceeds 100 feet, a larger size pump probably would not be purchased for this installation.

The necessary power of engine is shown by Table 5 to be between 2½ horsepower required for 100 feet of head and 3 horsepower for 120 feet of head, or it may be computed thus (see p. 14):

$104 \times 30 \div 4{,}000 = 0.78$ horsepower, pump output required;
$0.78 \times 3\frac{1}{3} = 2.60$ horsepower required of engine.

It will be advisable to purchase a 3-horsepower engine, as 2 horsepower probably will not be sufficient to operate the system with complete satisfaction.

A bill of material and estimate of cost for this irrigation system are given in Table 7, which shows a total cost of $563.07 for the pump and engine, pipe and fittings, tools, and minor supplies, but does not include the important items of water supply, foundations and housing for the machinery, posts to support the nozzle lines, freight, hauling, and labor. The table serves to illustrate how a cost estimate should be prepared, rather than what the cost of this system would be at any particular place.

ALTERNATE PLANS

If the pump and well were located at the middle instead of the end of the main, the friction loss in the main would be cut in half, but in this case would not change the size of engine to be purchased.

If the well and pump were located at the middle of one side of the field and the main run directly across the field beside a farm road, the installation would be made just as shown in Figure 4, using 1¼-inch pipe under the road. There would be a saving of 175 feet of 2-inch main, partly offset by the additional 1¼-inch pipe and fittings.

The location of the pump and water supply close beside the main of the distribution system is the most favorable condition, but is

not always to be obtained. Water from a stream or pond usually has to be pumped some distance to the irrigated field, and sometimes is at a level considerably below the field. Assuming that the water would be taken from a large pond 300 feet from the field, where the low-water level will be 75 feet below the highest ground in the field, the total head when 30 gallons per minute are being pumped would be computed thus:

	Feet
Lift from pond surface to highest ground	75
Height of nozzle line above ground	6½
Friction in 300 feet of 2-inch pipe (pond to field)	11½
Friction in main on side of field (350 feet)	13½
Pressure at nozzle line (20 pounds)	47
Total head	153½

As the ordinary pumps should be reduced in speed where the head exceeds 100 feet, the 5 by 5 inch pump and 3-horsepower engine may be expected to deliver about 20 gallons per minute under this condition without undue strain on the machinery and piping, if the speed of the pump is properly reduced. To deliver 30 gallons per minute against this head, according to Table 5, an engine of 3.8 horsepower or more should be used. A suitable outfit for these conditions would be the 6 by 6 inch pump and 5-horsepower engine, which could safely deliver about 35 gallons per minute at this head.

OPERATION AND UPKEEP

In applying irrigation water it is desirable to thoroughly moisten the ground to the bottom of the root zone at each irrigation. On clay soils the application must be slow enough not to puddle the soil, which requires more frequent turning of the nozzle lines than is necessary on lighter soils or the use of nozzles with smaller holes. Water should be applied as frequently and in such quantities as are needed to keep the soil in the best condition for the particular crops being grown; the ground should not be allowed to get dry and then be soaked with a heavy application. During operation of the system an average of about 10 minutes once each hour is required for turning the nozzle lines to distribute the water properly, for cleaning an occasional obstructed nozzle, and for attending the pump and engine.

The smaller spray-irrigation systems in the humid region are operated such a small part of the time that the operating cost is not important. The actual time of operation varies greatly from year to year, depending upon the length of the growing season and the distribution of the rainfall during the season. For systems covering 1 to 4 acres in the Middle Atlantic States the pumps are operated probably an average of only 100 hours per year, equal to only ten 10-hour days in 12 months. The cost of gasoline and oil for running a 3-horsepower engine is about 7 cents per hour, or about $7 for an average year.

The machinery should have an annual overhauling just after the irrigation season; the piping system should be drained before winter, and flushed out in the spring. The expense for the ordinary repairs may cost $5 to $10 per year for a small system; the labor of overhauling the system and making the repairs might average one full day a year for one man.

The pump and engine used only for irrigation and properly cared for should last at least 15 years and the overhead piping very much longer. Wooden posts may need to be replaced somewhat more frequently, depending upon kind of wood and preservative treatment. On the whole, the yearly cost of renewals and replacements ought not to exceed an average of 5 or 6 per cent of the original cost.

PROFITS FROM SPRAY IRRIGATION

Spray irrigation has been very profitable in many instances, and that it is generally profitable in at least some regions is indicated by the increasing number of systems installed in several Eastern States. But no attempt is made here to state what those profits have been or what profits a prospective irrigator may expect to obtain from irrigation. It is intended merely to point out the general method of computing the profits in a particular case.

The prospective irrigator should bear in mind that not all crops will increase in value, due to irrigation, sufficiently to give a reasonable profit on the cost of installation, operation, and upkeep of the irrigation equipment. In order to be profitable, a crop must increase in value sufficiently to pay (1) the cost of producing and marketing that increase, including the cost of additional seed, fertilizer, crates or other containers for the crops, and labor; (2) the cost of operating the irrigation system, including labor; (3) the cost of repairs; (4) a charge for depreciation, which would be an average each year sufficient to cover the renewal of all parts of the system at intervals; and (5) a reasonable interest charge on the original cost of the system. In computing the original cost and the cost of operation, the value of the owner's labor should be included even though it does not involve a cash payment, for it is to be assumed that the same time could have been used otherwise with profit.

The amount that the increase in net returns from the land exceeds the other costs of irrigation is the amount received as interest upon the investment, which is a convenient way of determining whether the system will be profitable. It may be computed in the following manner for an assumed installation costing $600 on 2 acres.

Average cost of fuel and oil for pumping	$7
Labor in operating system	17
Repairs to system, materials and labor	12
Depreciation, 6 per cent on $600	36
Average annual charge except interest	72

The installation cost thus is $300 per acre, and the annual charge is $36 per acre omitting interest. If the increase in value of crops sold exceeds the increase in cost of producing the crops by $50 per acre, the difference of $14 per acre will be the amount of interest earned, or 4⅔ per cent on the investment of $300 per acre. If the increase in net returns is $100 per acre, the interest will amount to $64, or 21 per cent on the investment.

The net returns from irrigation in the Eastern States vary widely from year to year, owing to market and weather conditions, and in some years may even represent a loss rather than a profit. The estimated average for the life of the system is the proper basis for computing profits; but it is a very uncertain quantity, especially in regions where irrigation previously has not been tried.

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